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TANOAK LANDSCAPES: TENDING A NATIVE AMERICAN NUT TREE

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ABSTRACT

Notholithocarpus densiflorus (Hook. & Arn.) Manos, Cannon & S.H. Oh (Fagaceae) (tanoak) needs immediate conservation attention due to the threat posed by *Phytophthora ramorum* Werres, de Cock & Man in't Veld, the water mold responsible for sudden oak death. This article explains the significant cultural value of tanoak and the seriousness of the sudden oak death threat. Current efforts to limit the spread of *P. ramorum* are not working adequately to prevent pathogen spread and maintain healthy ecosystems. The heartland of tanoak's distribution in northern California is at risk. I advocate for a collaborative process with tribal leadership to identify areas with mature tanoaks where traditional indigenous burning practices can be tested in combination with best management practices informed by western science. New approaches are needed to tend to tanoaks despite the sudden oak death pathogen and other threats.

Key Words: *Lithocarpus densiflorus*, *Notholithocarpus densiflorus*, tanoak, traditional ecological knowledge.

A century ago a non-native disease inadvertently introduced on an infected garden plant began to spread in North America's eastern deciduous forests. Within decades the once widespread American chestnuts (*Castanea dentata* [Marshall] Borkh.) succumbed to chestnut blight and no longer produced nutritious nuts for people, livestock, and wildlife in most of its native range (Freinkel 2007). Today, a similar fate may await a West Coast native nut tree: tanoak, *Notholithocarpus densiflorus* (Hook. & Arn.) Manos, Cannon & S. H. Oh. Since the horticultural trade accidentally introduced the sudden oak death (SOD) pathogen to North America, over a million tanoaks have died (Meentemeyer et al. 2011), and an unknown number are infected. The disease was first detected in California in the mid-1990s (McPherson et al. 2005; Kluza et al. 2007), and it continues to spread despite the efforts of landowners, scientists, and government agencies. Currently no cure exists for infected trees, and thus far tanoak exhibits little genetic resistance to the exotic water mold that causes the disease: *Phytophthora ramorum* Werres, de Cock & Man in't Veld (Hayden et al. 2011). Computer models rank uninfected areas on the north coast of California as high risk for infection (Meentemeyer et al. 2004; Kliejunas 2010).

Tanoak deserves more conservation attention due to its cultural and ecological importance. This magnificent tree, along with its relative American chestnut, reminds us that even common plants can rapidly become threatened. Fortunately large areas with extensive tanoak stands remain uninfected. The southern-most populations near Santa Barbara and inland populations away from the coast are probably too dry to foster SOD. However, because "an alarming number of uninfected forest ecosystems … face considerable risk of infection" plant pathologists recommend "that we develop effective management strategies for susceptible forests and that we prevent long distance spread of the pathogen, a threat that could drastically alter forests in California" (Meentemeyer et al. 2004).

THE BEAUTIFUL TREE

In the Kashaya Pomo language, tanoak is called *chishkale,* which translates to "beautiful tree" (Gifford 1967). In 1889, the first botany professor at the University of California at Berkeley, Edward L. Greene, called tanoak "the most remarkable of all North American oaks" and listed it as being "among the most beautiful of Californian forest trees" (Greene 1889). Generally a medium sized tree, its height typically ranges from "15.2 to 27.4 m" with a maximum height recorded at 63.4 m (Tappeiner et al. 1990). Diameter at breast height in mature trees ranges from "15 to 122 cm" and "the largest diameter of record is 277 cm" (Tappeiner et al. 1990). The overall shape of this evergreen tree varies greatly depending on growing conditions. However, two common forms exist, one that grows in full sun and another in dense shade. In open stands dominated by hardwoods, tanoaks form a broad, dense crown and a short trunk with robust horizontal branches. In shady, dense coniferous forests, tanoaks often grow as tall as 45.7 m with a branchless trunk that is "clear for 9.1 to 24.4 m" (Tappeiner et al. 1990). Taller trees with long trunks growing with coniferous competition lend themselves to wood production while the trees grown in sunny exposures generate a greater abundance of food in the form of acorns (Fig. 1).

FIG. 1. Tanoak in open prairie with robust canopy, a legacy of frequent, low-intensity fires set by Native people. Ukiah, California, circa 1903. Photograph by A. O. Carpenter (Plate 7 in Jepson 1910). Image courtesy of the University and Jepson Herbaria Archives, University of California, Berkeley.

As is typical for members of the Beech Family (Fagaceae), tanoak has unisexual flowers. The tree can flower during any season except winter, but typically blossoms appear in June, July, or August with coastal and low-elevation trees blooming earliest (Roy 1957b). The small, solitary female flowers aggregate at the base of the erect male catkin, each subtended by a small bract (Fig. 2). The abundant yellowish-white male spikes "light up the tree like candles at Christmas" (Fig. 3) (Peattie 1991). Drought during pollination fosters greater seed set (Tappeiner et al. 1990). Once pollinated via wind or insects, acorns mature after two years. Tanoak's simple leaves alternate on the stem. Notorious for being highly variable, the leaves are "leathery to brittle" with serrated to toothless edges and often revolute margins (Nixon 1997). The usually smooth and shiny leaves are densely wooly beneath initially but much of the hair wears off with age. The thick, grayish-brown bark becomes fissured with age. Tanoaks are often difficult to reliably age due to heart rot and the high frequency of suckering if killed to the ground. Its hard wood also makes coring a tanoak trunk to count growth rings quite challenging. However, throughout its range, 180 years appears to be a typical maximum age in unlogged forests, with estimates reaching as high as 300–400 yrs (Fryer 2008).

Tanoak trees grow from southwestern Oregon through the California Coast Range to near Santa Barbara, with inland populations occurring through the Siskiyou Mountains and from the southern tip of the Cascade Range along the western slopes of the Sierra Nevada to Yosemite National Park (Tappeiner et al. 1990; Tucker 2012). The shrub variety, *Notholithocarpus densiflorus* var. *echinoides*, (R. Br.) Manos, Cannon & S. H. Oh extends from southwestern Oregon to northern California's Klamath Range, Cascade Range, and Sierra Nevada. A mutant, shrub-like form grows in Yuba County in the northern Sierra Nevada (forma *'attenuato-dentatus'*) (Tucker et al. 1969). This mutant is used in horticulture due in part to its rarity. It has a maximum height of roughly 2.4 m. and unusual, deeply serrated, narrow leaves, each with a very narrow apical tip. No other taxa belonging to this genus exist on the planet. A prominent U.C. Berkeley botany professor, Willis Linn Jepson, wrote in 1910 that tanoak is "exceptionally well-fitted by its reproductive powers, vigor and shade endurance to take part in the struggle for continuous possession of the land"—hence its other common name, sovereign oak (Jepson 1910).

Early Indigenous Peoples' Use of Tanoak

Tanoak acorns formed the basis of a California Indian acorn economy for thousands of years (Fig. 4). Today they remain a highly valued food among indigenous tribal peoples. In northern California, at least after American settlement, salmon was the only other food consumed in larger quantities. Though indigenous peoples gathered and favored acorns from multiple oak species, northwestern tribes in particular often preferred tanoak when obtainable (Gifford 1971; Chestnut 1974; Heizer and Elsasser 1980). E. W. Gifford, an academic expert on acorn eating or balanophagy in California, ranked tanoak number one in popularity and black oak (*Quercus kelloggii* Newb.) second (Gifford 1971). Although controversial, anthropologist Martin Baumhoff defended rating as important "because in many areas people would travel a long way to a single tree of a preferred species while ignoring nearby groves of an undesirable species" (Baumhoff 1978). Three remnant Tolowa tanoak groves totaling roughly 500 mature trees along the Smith River were estimated to annually produce "14.4 tons … of usable food materials when dried" (Gould 1976).

In addition to serving as a staple food, tanoak was used in the making of fishing nets, baskets, and medicines. The Tolowa used tanoak bark to dye their nets in order to make them less visible to fish (Baker 1981). Since tannins have a history of being used to preserve fibers such as cloth sails for ships as well as fishnets, the Tolowa may have gained longer use of their nets (Schniewind 1958).

FIG. 2. Tanoak twig with female flowers, male flowers, male catkins, and acorns. Illustration by Charles Edward Faxon (Tab. CCCCXXXVIII in Sargent 1895).

The Costanoan/Ohlone also prepared a dye from tanoak bark (Bocek 1984). Oak saplings including tanoak were used in heavy-duty baskets. In baby baskets tanoak served to protect the infant's head. The oak rim of hopper baskets used during acorn pounding needed to be strong because women rested their legs on it to hold it in place around the mortar (S. Smith-Ferri, Grace Hudson

FIG. 3. Tanoak portrayed in Curtis's botanical magazine (Tab. 8695 in Prain 1917).

Museum, personal communication, 14 September 2011). Among the Kashaya Pomo, tanoak acorns functioned as cough drops as the tannins suppressed coughing (Goodrich et al. 1980). The Costanoan/Ohlone used a tanbark decoction to treat facial sores and loose teeth (Bocek 1984). Tanoak was so highly regarded by the Sinkyone that "[d]reams of tanoak … were a sign of good luck" (Nomland 1935).

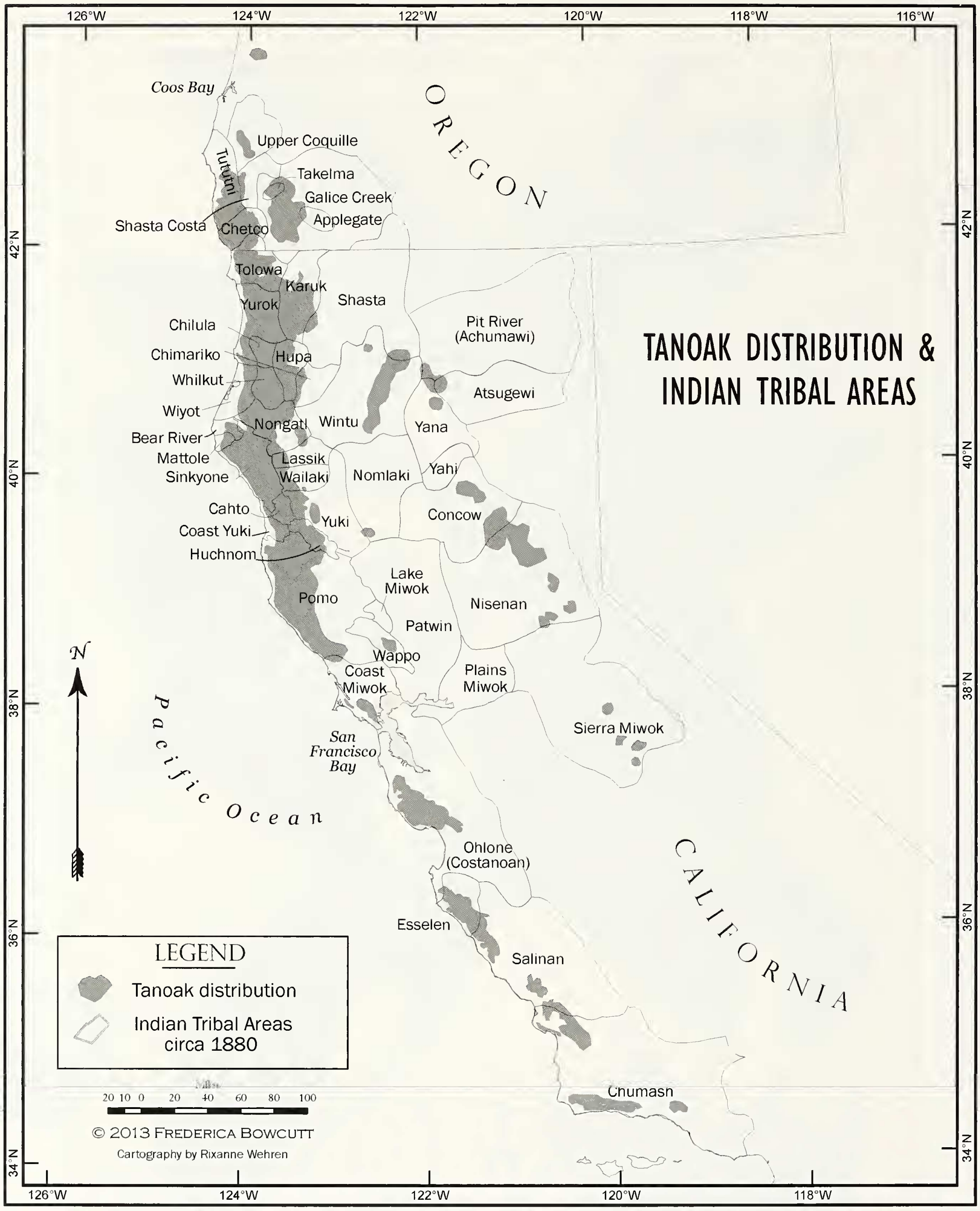

FIG. 4. Tribal territorial map and tanoak distribution. Data sources: M. Kat Anderson, USDA-NRCS, provided the tribal boundaries digital map layer for California. Minor adjustments were made based on data provided by Jerry Rohde, Cultural Resources Facility at Humboldt State University; Hawk Rosales, executive director of the InterTribal Sinkyone Wilderness Council, and the American Philosophical Society (2012). The tribal boundaries for Oregon were derived primarily from Schaeffer (1959). The tanoak distribution data for California came from Griffin and Critchfield (1976). Tanoak distribution data for Oregon came from the Oregon Flora Project (2012).

Multiple characteristics of the acorns contribute to tanoak's popularity as a staple food among many California Indian tribes. A thicker shell makes the delicious nut more resistant to fungal and insect attacks (Wolf 1945; Heizer and Elsasser 1980). Tanoak acorns store for years, making them a desirable trade item. For example, the Karuk (or Karok) swapped tanoak acorns for "white deer skins, obsidian, dentalia shells, and Sugar Pine nuts" with Shasta people (Davis 1991). Relative to other oaks, tanoak is one of the more reliable producers, rarely failing completely and bearing bumper crops more frequently. Tanoaks "are heavily laden almost every alternate year and complete seed crop failures are rare," helping to give it the reputation of being the heaviest acorn producer of all Pacific Coast oak species (Roy 1962). Annual nut production in most other nut-bearing trees varies significantly with heavy crops every two to five yrs. The "non-mutually exclusive hypotheses" proposed for this masting behavior include, genetics, climatic conditions, and coevolution with seed eating animals to limit their population growth (Vander Wall 2001). Tanoak trees typically begin to bear an abundance of acorns when they've reached between 30 and 40 yrs old, "although 5-year-old [root] sprouts also have produced fairly heavy crops" (Roy 1962). A mature tanoak tree bears more than 90 kg of nuts on average in a good year, with estimates as high as 454 kg annually for old growth trees (Radtke 1937; Baumhoff 1963). Each nut typically exceeds the size of a hazelnut.

Compared to grains like wheat, tanoak acorns are low in protein but superior in caloric value due to the high amount of nutritious fats they contain (Table 1) (Baumhoff 1963). Nutrition scientist Linda Ellen Gilliland completed a study in 1985 in which she found that protein and fat content varied significantly in acorns, but she corroborated that protein content is low and fat and carbohydrate content are moderately high in tanoak acorn foods. However, she did not analyze mineral content for tanoaks as suggested in the title of her thesis (Gilliland 1985). More research is needed on the nutritional value of tanoak acorns, because many other health-promoting constituents exist in plant foods other than fat, fiber, carbohydrate, and protein. Acorns are soft enough to chew without processing, but the tannic acid they contain must be removed to make them useful as human food (Essene 1942). Compared to most acorns, tanoak nutmeats are significantly larger, making them easier to process.

Tanoak-acorn harvesting occurred and continues to occur during autumn. Based on the ethnographic record, Karuk families gathered in October for roughly a month (Schenck and Gifford 1952). The Yuki collected tanoak acorns "far up in the mountains in November when they were ripe" at higher elevation (Curtin 1957). Collecting often occurred some distance from winter residences. The Tolowa moved to the inland edge of the redwood belt for a month to gather nuts before moving back to coastal villages (Gould 1976). According to Pomo ethnographer Fred Kniffen, "no trip was too long to make for these highly desired nuts" (Kniffen 1939). Families picked up acorns under tanoak trees after they fell naturally. Some tribes used sticks to knock acorns down, although others believed this practice was harmful to the trees as it can cause nuts in their first year of development to fall, thus reducing the following year's harvest. Pomo men climbed mature trees or, if smooth barked, they used "a sapling or a fallen redwood as a ladder" and then stamped "on the branches to shake" acorns down (Gifford 1967). Openwork burden baskets were used to transport the harvest (Shanks and Shanks 2006).

Annual first-acorn ceremonies preceded consumption of the nuts each autumn (Wallace 1978). Among the Sinkyone this ceremony lasted five nights (Nomland 1935). Mary Socktish, an officiate of the Hupa's first acorn feast, recounted in 1940 the associated rituals. Typically, in early October or rarely in late September, she and several other women harvested the earliest ripe acorns. The night before the feast, she prayed for "plenty of acorns," addressing her request to "the acorn 'boss'—Yinukatsisdai, the god of vegetation." Several other women assisted her in praying for a good harvest most of the night in the "sacred living house." After bathing at three a.m. in the cold river, the women began to de-skin, winnow, pound, and sift the already shelled acorns. Around sunrise, the women took the acorn meal to the river for leaching and cooking at the feasting place. "While the stones are heating, we prepare fall salmon, broiling it on sticks around the fire. … After the acorn meal is all cooked, about two o'clock in the afternoon, a messenger is sent to notify the people to come to the feast. The people come along a special trail." Socktish warned: "Whoever wastes acorns at any time will not have plenty" (Kroeber and Gifford 1949).

Indigenous peoples developed food technologies for storing, processing, and cooking tanoak

TABLE 1. NUTRITIONAL COMPOSITION BY PERCENTAGES OF SELECT ACORNS COMPARED TO BARLEY AND WHEAT. Adapted from page 25 of Basgall (1987), and page 162 of Baumhoff (1963).

Species	Fats	Fiber	Carbohydrates	Protein
Black oak (*Quercus kelloggii*)	11.1–18	11.4	55.5	3.4–4.6
Blue oak (*Q. douglasii*)	4.8–8.1	9.8	65.5	3.0–5.5
Canyon oak (*Q. chrysolepis*)	8.7	12.7	63.5	4.1
Coast live oak (*Q. agrifolia*)	14.5–16.8	11.6	54.6	3.1–6.3
Oregon white oak (*Q. garryana*)	4.5	12	68.9	3.9
Valley oak (*Q. lobata*)	4.2–5.5	9.5	69	2.8–4.9
Tanoak (*Notholithocarpus densiflorus*)	12.1	20.1	54.4	2.9
Barley	1.9	5.7	71.0	8.7
Wheat	1.8	2.3	69.4	12.3

acorns to yield a sweet, nutty meal rich in complex carbohydrates and essential fatty acids. Storage inside homes helped to protect against rodents (Baumhoff 1963). Among the Lassik, all tanoak acorns were stored inside while other acorn types were stored outside at least in part indicating how valued tanoak acorns were (Essene 1942). Pomo women reduced spoilage by drying whole tanoak acorns in the sun before storage, using ultraviolet radiation to kill mold and other fungi. California Indian people used a hammerstone to crack open acorns placed on a flat rock (Driver 1952). The Karuk kept hulled tanoak acorns in their homes after drying them on basket plates. The drying acorn meats were occasionally shaken and then rubbed and winnowed to remove their thin skins (Schenck and Gifford 1952).

Outdoor storage allowed for significant stockpiles. Many tribes created granaries to store excess acorns for future daily use, feasts, and trading. Sometimes these were long distances from a village. Made from woven tule (*Schoenoplectus acutus* [Muhl. ex Bigelow] Á. Löve & D. Löve var. *acutus*), coppice growth of willow (*Salix* spp.), or other woody plants (wattle) and/or conifer boughs, these silos often perched on branch legs to elevate them off the ground. Construction practices varied among tribes and over time. During the winter months, when fresh foods were scarce, stored acorns took on even greater importance in the diet.

Many preparation methods existed. Initially indigenous peoples only processed the nuts either un-hulled or hulled but never crushed. Multiple tribes immersed or buried acorns whole to extract bitter tasting tannic acid including the Yurok, Hupa, Pomo, and Yuki (Gifford 1968). The Karuk prepared un-pulverized tanoak nuts by placing them in a hole and pouring water over them "for several weeks until they became soft and turned black" (Davis 1991). A southwestern Pomo preparation method involved nuts placed in a pool with the hull cracked but left on. After four or five months, the mushy, tannin-free acorns were hulled and cooked whole (Gifford 1967). As in the preparation of cheese, yogurt, and wine, fungi are sometimes factored into acorn preparation. After several weeks in a Pomo home, hulled but still whole nuts molded. After the greenish patina was rubbed off by hand, women ground the nuts and used them to give dishes a sour flavor much like vinegar and salt (Gifford 1967). Sometimes people roasted or boiled whole nuts, too. However, leaching whole nuts in water or mud required a great deal more processing time to remove enough tannic acid.

Thousands of years ago, women developed a much faster way to process acorns. Pulverizing then leaching became the preferred mode of preparation and dominated where acorns served as a staple food (Driver 1952). This radically quicker leaching process liberated a "vast new food supply of high nutritive value" (Gifford 1968). In California's North Coast Ranges, anthropologists have uncovered milling implements as old as 5000–7000 yrs (Basgall 1987). From archeological sites in the southern end of the North Coast Ranges, "the slab and handstone represented the primary milling technology until about 3000 B.P., after which the mortar and pestle became increasingly more important" (Basgall 1987). A flat milling slab combined with an elongated stone or mano typically served to grind the small, hard seeds of mostly grassland plants (pinole), while the stone mortar and pestle served primarily to pulverize acorn-meats and other oily nuts (Chartkoff and Chartkoff 1984; Basgall 1987). Oak logs with depressions sometimes served as mortars, too (Driver 1952). In Potter Valley and other areas in northwest California, women used oak mortars (S. Smith-Ferri, Grace Hudson Museum, personal communication, 14 September 2011). They used bottomless basket hoppers on their mortars to keep meal in place during the acorn-pounding process.

The practice of pounding acorns and then leaching the meal with water in a sand basin or basket became widespread between 4000 and 2000 B.C. (Fig. 5) (Chartkoff and Chartkoff 1984). Prior to leaching, Karuk women sifted the acorn meal "in a tight, flat basket, the coarse stuff being removed by tapping the basket with a stick" (Schenck and Gifford 1952). Sifting practices varied among different indigenous peoples, but essentially it involved separating out the still coarse material to repulverize it. During the leaching process, the Karuk used increasingly warmer water. When whites introduced metal pots in the mid-19th century, Round Valley Reservation cooks adapted to leaching almost entirely with warm water to hasten leaching time (Essene 1942). Traditional cultural practitioners persisted with the slower method of using cold water (Essene 1942). Heated water extracts the tannic acid faster, but cold water leaves more of the nutritive value including the high-quality fats. Periodic taste-testing during the leaching process serves to indicate when the bitter tannic acids have been adequately removed. Some people like the taste of a little tannic acid, while others like a more leached acorn food because it tastes "sweet" or bland. Most people eat prepared acorns with salmon, venison, or honey. The preferred consistency of tanoak acorn food varies from a watery soup to a thick porridge.

Worldwide, the acorn-food technologies of California are among the most developed. People across the globe used (and continue to use) acorns from various oak species as food, but tannic acid removal practices varied or were lacking entirely. Indigenous people in central Arizona only ate unleached, sweet acorns, thus

FIG. 5. Mrs. Freddie (Hupa) leaching acorn meal in 1902. To her left appears an open-weave acorn-collecting basket. Courtesy of the Phoebe A. Hearst Museum of Anthropology and the Regents of the University of California. Photograph by Pliny E. Goddard (Neg. No. 15-3329).

neglecting acorns with more tannin that yielded a bitter taste. This was true in Mediterranean regions as well, such as Spain. In Mexico, people neglected acorns entirely as food. Most east coast tribes of North America boiled acorns prior to pulverizing to make them palatable, as did people in Japan. On the island of Sardinia in the Mediterranean Sea, human beings boiled and then ground acorns, but they mixed iron-oxide–rich clay with meal to "counteract the tannic acid" in the same way Pomo women do when making acorn bread from black oak acorns (Gifford 1968). In the southeastern United States and Persia, people pounded then leached acorns like California Indians (Driver 1952).

Once leached of the bitter tannins, Native California women cooked tanoak acorn soup or porridge with hot rocks placed in baskets, using two sticks often with loops at the ends. To avoid burning the baskets, women kept the hot rocks moving with wooden paddles. Cooks used extreme caution in selecting rocks that would not explode when they were dunked in water to rinse off ashes before placing them in the cooking basket (S. Smith-Ferri, Grace Hudson Museum, personal communication). Many women inherited their cooking rocks from female relatives. This method of cooking was fast, and the resulting food was served in dedicated basket bowls or cups. Karuk cooks gave the cake that formed on hot cooking rocks to children as a special treat (Baker 1981). The Kashaya Pomo preferred (and still prefer) tanoak acorns for cereal and soup, while favoring black oak or valley oak (*Quercus lobata* Née) acorns for unleavened acorn bread prepared in an earthen oven (S. Smith-Ferri, Grace Hudson Museum, personal communication, 14 September 2011). Sometimes the Karuk used hot coals to bake patties from tanoak acorn paste (Baker 1981). Along with other abundant native foods such as pinole and salmon, tanoak acorns made possible a settled existence in a relatively small area. A single, well-tended tanoak grove could meet the needs of a tribal village without supplemental irrigation or inordinate amounts of physical labor (Heizer and Elsasser 1980).

Traditional Ecological Knowledge

To maximize acorn production, indigenous peoples manipulated vegetation on a landscape scale using fire. Burning practices involving frequent, typically low-intensity fires developed in response to climate change. About 6000–5000 yrs ago a warm, dry spell, called the Xerothermic, facilitated the expansion of oak woodland and prairie on the West Coast. Between 4500 yrs ago to the present, the climate changed again to wetter, cooler conditions, and as a result Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) and other conifers spread at the expense of oak woodland and prairie (Briles et al. 2005). Fire favored acorn-producing tanoaks and pinole-producing prairies over conifers. Pinole was made from a variety of grassland seeds such as tarweed (*Madia* spp.) and California oat grass (*Danthonia californica* Bol.). It is difficult to know how significant acorns were relative to pinole in the indigenous diet prior to American settlement. This is due to the rapid changes in grasslands with the advent of livestock grazing and the conversion to non-native orchard grasses, row crops, and towns. What is clear is that Native peoples engaged in a kind of permaculture and agroforestry using native species. By design they created cultural landscapes with fire, where grassland and tanoak groves thrived in a region naturally dominated by coniferous forests. Evidence for intentional burning exists in the ethnographic record, in the ecological response to fire, and in microfossil research (Bicknell, unpublished). The historic record also provides supporting evidence including serial photographs documenting vegetation change over time (Bowcutt 1994–1996; Bowcutt 2011).

The anthropological literature documents indigenous burning as widespread to favor tanoaks and associated prairie on the North Coast of California. The Lassik kept "much of their territory … completely clear of underbrush" through frequent, low-intensity ground fires, particularly along the Eel and Mad rivers. According to the informant, "much of Trinity County" was "almost open prairie," but by 1938 it was "choked with thick brush" (Essene 1942). Ethnographer Llewellyn Loud claimed in 1918 that prairies would have produced forests if the Wiyot Indians didn't annually burn "so as to gather various seeds, especially a species of sunflower." The location of these food oases was well known by the Wiyot and they "maintained regular trails between them" (Loud 1918). In addition to making human travel easier, burning cleared the ground before acorn harvesting (Schenck and Gifford 1952; Beard 1979). After completing their acorn harvest, the Tolowa burned the inland tanoak groves that they "heavily exploited" before returning each year to their coastal villages (Gould 1976). Ethnographer Gladys Nomland noted that Sinkyone "[m]en fired grassy meadows" to foster food production (Nomland 1935). Even myths point to burning as a common cultural practice. Alfred Kroeber, Nomland's professor at the University of California at Berkeley, recorded a Sinkyone story that featured buzzard flying "over the dry grass. Wherever he went, he fired the grass, and the flames spread" (Kroeber 1919). The Pomo Indians of Redwood Valley burned annually to maintain widely spaced oaks with a grassy understory. In their "beautiful park landscape," burning controlled the brush while leaving "the larger trees … uninjured" (Kniffen 1939). By decreasing fuel loads, regular burning by tribal peoples reduced the risk of catastrophic wildfire that would destroy mature tanoak trees (Anderson 2005).

Frequent burns minimized loss of tanoak acorns to diseases, insect pests, and unfavorable climatic conditions. A Karuk woman, Mamie Offield, explained to an ethnographer that annual burning protected tanoak from infection and insects (Schenck and Gifford 1952). It reduces insect populations because trees abort acorns infested with weevil and moth larvae during development, thus a ground fire set after initial acorn drop kills the larvae inside and those already in the leaf litter (Warburton and Endert 1966; Vander Wall 2001). Filbert weevils (*Curculio uniformis*), filbertworm moth larvae (*Cydia latiferreana*), and other insects can destroy over half of the acorn crop (Roy 1957b), particularly in the absence of frequent fires. By clearing underbrush, Indian people maintained good airflow around harvested tanoaks, which reduced loss of flowers and developing acorns to cold temperatures. Unfavorable climatic conditions also provoked the southwestern Pomo to pray for acorns "when hail comes from the north" (Gifford 1967). Tanoak acorns ripen in their second autumn, thus increasing their vulnerability to late frost. Current trends in global climate change indicate that "day-to-day weather has grown increasingly erratic and extreme," which "could have consequences for ecosystem stability and the control of pests and diseases" (quote from Kelly 2011; see also Medvigy and Beaulieu 2012).

Ecological evidence bolsters the argument that Indian people burned to foster wildlife including species they hunted. Repeated fires favor tanoak over non-sprouters like Douglas-fir (Lewis 1993). The coppice growth after burning from tanoak's basal burl provided basket materials and browse for deer and elk. Deer and bear fatten on tanoak acorns before winter. Many other wildlife species cache acorns for later consumption, such as squirrels, woodpeckers, and jays. Some animals, such as various salamanders and rodents, use tanoak for cover and/or nesting, while certain mammals prey on tanoak herbivores (Raphael 1987). To leave enough for animals, "many native people in northwestern California … stop acorn harvest after November" (Hosten et al. 2006). For a partial list of animals that eat tanoak acorns, see Table 2.

Research based on microfossils provides evidence that vegetation has shifted in relation to changing climate and fire frequency over the last 15,000 yrs. Pollen cores extracted from wetlands in the Siskiyou Mountains of Oregon indicate that during the last glacial period (>10,900 cal yr B.P.), subalpine forest extended to lower elevations and latitudes than it does today. During the early Holocene (ca. 10,900–4500 cal yr B.P.), the climate shifted to "warmer-and-drier-than-present summer conditions," favoring xerophytic

Table 2. Some Wildlife Species that Consume Tanoak Acorns (Roy 1957a; Fryer 2008; ITIS 2011).

Animal type	Common name	Scientific name
Birds	acorn woodpecker	*Melanerpes formicivorus*
	band-tailed pigeon	*Patagioena fasciata fasciata*
	varied thrush	*Ixoreus naevius naevius*
	Steller's jay	*Cyanocitta stelleri*
Mammals	American black bear	*Ursus americanus*
	California ground squirrel	*Spermophilus beecheyi*
	Columbian black-tailed deer	*Odocoileus hemionus columbianus*
	Douglas squirrel	*Tamiasciurus douglasii mollipilosus*
	dusky-footed woodrat	*Neotoma fuscipes fuscipes*
	mule deer	*Odocoileus hemionus*
	northern flying squirrel	*Glaucomys sabrinus*
	raccoon	*Procyon lotor*
	Townsend's chipmunk	*Tamias townsendii*
	western gray squirrel	*Sciurus griseus*

species such as oaks and chinquapin (Briles et al. 2005). Xerophytic vegetation contracted when the climate became cooler and wetter during the late Holocene (ca. 4500 cal yr B.P.–present), except where burned regularly by Native peoples. Fossilized pollen of tanoak resembles chinquapin pollen, making fine-grained vegetation reconstruction difficult (Briles et al. 2005). However, pollen evidence indicates that indigenous burning changed vegetation elsewhere in the West. For example, in Yosemite Valley, *Quercus* pollen begins to increase about 700 yrs B.P. despite climatic conditions that favored fir (*Abies*). Archeological evidence indicates indigenous peoples of Yosemite Valley became more dependent on oak acorns between 650–750 B.P., thus giving them an incentive to burn frequently to kill pines. "At contact [with Euro-Americans], much of the valley was an open oak-grassland with few conifers. However, after nearly three-quarters of a century of fire suppression or exclusion, the valley was choked with shrubs and young conifers" (Anderson and Carpenter 1991).

Paleobotanical research based on phytoliths, another kind of microfossil, indicates that coniferous forests and coastal scrub have expanded with fire suppression over the last century on the northern coast of California. Humboldt State University professor Susan Bicknell found an abundance of phytoliths unique to grasses in areas now dominated by conifers in Sinkyone Wilderness State Park on the northwestern Mendocino coast (Bicknell unpublished). These silicon dioxide deposits originate between and inside plant cells and can persist in the soil for millions of years. Researchers use phytoliths to study vegetation change over time. Bicknell and her graduate students also found Douglas-fir seedlings, saplings, and trees in nearly all their grassland and scrub plots, which lead them to conclude that this conifer could naturally occupy most sites in the park.

The historic record documents prohibitions on indigenous burning and the radical transformation in vegetation that followed. In regions of California colonized by Spaniards, the "civil authorities issued edicts, such as Governor Arrillaga's command in 1793" that prohibited burning "to increase the productivity of wild foods" (Lightfoot 2005). In Humboldt Co., a geographic area in northern California with an abundance of tanoaks, the Euro-American settlers of the Mattole Valley passed a resolution in 1858 that the Indians "not set fire to the grass" (Bledsoe 1885). A collector of wild lily bulbs for the horticulture trade watched as beds he sustainably harvested over multiple years ultimately became overgrown and shaded out during the 1870s due to suppression of indigenous burning (Anderson 2005). Prohibition of Indian-set fires to manage the underbrush in Mendocino Co. caused a shortage of suitable basket-making materials, which was noted by a basket dealer in 1923 (Anderson 2005). Photographs taken over the last century document an increase in Douglas-fir and coastal scrub in Sinkyone Wilderness State Park at the expense of coastal prairie and associated tanoaks (Bowcutt 1994–1996).

Willis Linn Jepson, a University of California botany professor from 1899–1937, noted in 1910 that coniferous forests dominated more acreage in the West than when whites first arrived (Jepson 1910). Even prior to the ability to suppress fires on a landscape scale, the consequences of fewer human-set fires became apparent within decades of American settlement. Compared to resinous conifers, tanoaks are less flammable. Jepson claimed that, "fires rarely kill tanbark oak trees" (Jepson 1911). He wrote that trees more than 100 yrs old develop "long vertical wounds," which generally spread. However, if it does die down to the ground, tanoak resprouts from burls at the base of the trunk. Although seedlings are fire sensitive, scars heal over on surviving young trees (Jepson 1911). Mature, ridgeline tanoaks enjoy the most benefits from frequent burning. According to Jepson, "about 80 percent are comparatively free from fire hollows, because a

FIG. 6. Essie Parrish gathering acorns. Kashaya, Sonoma Co., California, 1960. Courtesy of the Phoebe A. Hearst Museum of Anthropology and the Regents of the University of California. Photograph by Josepha Haveman (Neg. No. 15-19440).

fire traveling up a slope is either running high or going out when it reaches the top" (Jepson 1911). Speaking in general about California forests, he noted that annual burning favors "under certain conditions the development of large individual trees." In contrast, even five to ten years of fire suppression resulted in fuel accumulation that could lead to destructive fires that "injure more severely or even consume large trees." Jepson concluded that, based on their skillful use of fire as a management tool, "some credit must be given to the native tribes as foresters" (Jepson 1909).

Contemporary Indigenous Use of Tanoak Acorns

Native people have continued to use tanoak acorns for human food since American colonization, albeit at a reduced scale. Assimilation efforts beginning in the late 1800s resulted in most Native people shifting to wheat as a staple. However, the early reservations were notorious for being unable to reliably feed, shelter, and clothe Indians. Reliance on wild foods continued and persists today. In 1938 a Lassik informant told a University of California anthropologist that "[i]f the Indians ain't got acorns, it seem like he ain't got nothing" (Essene 1942). Lulu Johnson, a Yuki woman, still prepared tanoak—or *shō'-kish*—acorn soup, mush, and pancakes for her family in the 1950s when they had "a longing for the taste of the nuts" (Curtin 1957).

In 1964, anthropologist Samuel Alfred Barrett produced a film on tanoak acorn use as part of the American Indian Film Project. Entitled *The Beautiful Tree, Chishkale*, it was made in collaboration with a Kashaya Pomo leader, Essie Parrish, and her family (Barrett 1964) (Figs. 6, 7). Barrett focused on what he perceived as authentic practices and intentionally did not document the adaptation of new tools like shovels, rakes, metal meat grinders, and pots to facilitate acorn harvesting and processing (S. Smith-Ferri, Grace Hudson Museum, personal communication). In reality, beginning in the mid-19th century, indigenous women had creatively repurposed the garden and culinary tools of Euro-American culture to serve their needs when obtaining and preparing tanoak-based foods.

While fire suppression, livestock grazing, and development diminished acorn crops throughout

FIG. 7. Essie Parrish preparing acorn meal. Kashaya, Sonoma Co., California, 1960. Courtesy of the Phoebe A. Hearst Museum of Anthropology and the Regents of the University of California. Photograph by Josepha Haveman, (Neg. No. 15-19554).

California, increasingly during the 20th century, the automobile facilitated travel to locations where the greatest number of acorns could be gathered which might vary from year to year. Some people shifted their collecting to mowed landscapes such as cemeteries to facilitate the process. Others were forced to gather at higher elevations than their ancestors had gathered, which often shifted the required schedule to ensure ripeness. Adaptability continues to be key to the efforts of keeping tanoak food traditions alive and vibrant.

Dishes made with tanoak acorns are still served at celebrations, tribal gatherings, and as a healing food for the sick and elderly (Fig. 8) (McCarthy 1993). Many health practitioners argue that adoption of a Western-style diet has contributed to the high rates of diabetes among indigenous people. According to the Centers for Disease Control and Prevention, "American Indian and Alaska Native adults are 2.6 times more likely to have diabetes than non-Hispanic whites of similar age" (CDC 2011). Medical research links diabetes with diets high in simple carbohydrates and low in healthy fats. Speaking in 1984, Hoopa tribal woman Winnie Marshall warned that in the future "everyone might have to rely on native foods to survive" (Marshall 1984). Note that Hoopa Valley tribal members may or may not be of Hupa ancestry. Unfortunately, most legacy tanoak trees were destroyed by the tanbark industry supplying tanneries between the 1840s and 1920s. And in the 1950s, softwood producers began poisoning tanoak with herbicide to favor marketable conifers in industrial forests (Bowcutt 2011).

Reviving old acorn economies is part of a worldwide movement of indigenous peoples uniting around issues of "cultural survival, ownership of knowledge or intellectual property rights, empowerment, local control of land and resources, cultural revitalization, and self-determination" (Berkes 1999). Many tribal peoples lost access to tanoak acorns through government land appropriation and relocation policies in the 19th century that moved tribes to inland locations that lacked dense, productive populations of the tree. Many California tribal people feel plants thrive in positive relationships with people (Anderson 1993). Tribal elders contend that "plants want to be used," and if

FIG. 8. Cooking tanoak acorns in fall 2011, from left to right Kayla Carpenter, Gina Balabas, and Melodie George-Moore, all Hupa Tribal members. Photograph by Laura Lee George.

they aren't, their quality deteriorates and their numbers diminish (Anderson 1993). For tanoak to thrive, human intervention with good intentions and skillful means may be required.

Native peoples rely on this important food source and are proactively seeking ways to foster tanoak well-being. Unfortunately, the possibilities for reestablishing managed tanoak acorn trees are limited. The densest stands occur in northwestern California near the coast, most of which are not on existing reservations or rancherias. A Pomo Indian said in a 1995 interview that his grandparents traveled some distance from Sherwood Rancheria to harvest roughly 135–180 kg of tanoak acorns from the same tree each year (Bowcutt 1996). The Karuk, Yurok, and Hoopa Valley Tribes have reintroduced burning on their tribal land to foster tanoak acorn production. The Hoopa also manually thin on their land to favor broad tanoak canopies for increased acorn production (Wilkinson et al. 1997). To create a productive, wide tanoak crown, foresters recommend thinning lightly over a period of time to avoid damaging trees by sudden exposure to sunlight after logging (McDonald and Tappeiner 1987; McDonald and Huber 1995).

The InterTribal Sinkyone Wilderness Council (hereafter, Council) was formed in 1986 to protect and preserve Sinkyone ancestral lands, and to revitalize local tribes' cultural land-stewardship practices (Bowcutt 2011). The ten federally recognized tribes in the Council include the Cahto Tribe of Laytonville Rancheria, the Coyote Valley Band of Pomo Indians, the Hopland Band of Pomo Indians, the Pinoleville Pomo Nation, the Potter Valley Tribe, the Redwood Valley Rancheria of Pomo Indians, the Robinson Rancheria of Pomo Indians, the Round Valley Indian Tribes, the Scotts Valley Band of Pomo Indians, and the Sherwood Valley Rancheria of Pomo Indians. In 1997, the Council purchased from The Trust for Public Land approximately 1556 hectares of aboriginal Sinkyone Indian land adjacent to the coastal Sinkyone Wilderness State Park. The Council's goals include reestablishing traditional stewardship of native species, such as tanoak, and reintroducing culturally informed prescriptive burning of coastal prairie and tanoak groves to improve tanoak health. This approach is consistent with contemporary ecological restoration of *Quercus*-dominated woodland, which often combines manual removal and prescribed fire "to reduce conifer density" (Fig. 9) (Reid and Sugihara 1987; Hosten et al. 2006).

Sudden Oak Death Threat

Diseased and dying tanoak trees were first noticed in the mid-1990s north of San Francisco in Marin Co. around Mount Tamalpais (McPherson et al. 2005). Plant pathologists ultimately concluded that a previously undescribed species was causing the observed bleeding stem cankers. The new lethal tanoak pathogen, *Phytophthora ramorum,* is not native to North America, but no one knows where it originated or when it arrived (Grünwald et al. 2012). *Phytophthora* means "plant destroyer," an apt name given the tanoak die-offs it has caused. By 2001, SOD had "reached epidemic proportions in forests along approximately 300 km of the central coast of California," from the Big Sur Coast to Sonoma Co. (Rizzo et al. 2002b). The water mold has spread through commerce in horticultural plants (Rizzo et al. 2005; Ivors et al. 2006; Marscheretti et al. 2008). Although tanoak has proved to be the most susceptible, many native California species and common nursery and landscape plants serve as carriers that help spread the pathogen (Rizzo et al. 2002a). Of the ornamental hosts most prone to spread the disease, plant pathologists list three genera in the Ericaceae (*Rhododendron, Pieris,* and *Kalmia*), *Camellia* (Theaceae), and *Viburnum* (Caprifoliaceae) (Frankel 2008). While fatal to tanoak and some other related tree species, most of its hosts suffer only shoot die-back or leaf spots and blotches. (An updated list of host plants is available at www.suddenoakdeath.org).

FIG. 9. Underburning in a tanoak stand in Humboldt Co., California, near the town of Orleans. Orleans/Somes Bar Fire Safe Council [OSB-FSC] implemented a prescribed burn in October 2010. Workers tending to the fire are Ben Beaver and Will Harling. Photograph by Frank Lake.

Researchers believe *P. ramorum* was introduced on imported nursery stock for North American gardens. Increased global trade is accelerating the worldwide spread of exotic diseases, which damages biodiversity and habitat health (Vitousek et al. 1996; Brasier 2008). According to Clive Brasier (2008), a senior plant pathologist,

> major problems may arise if a pathogen escapes – or is introduced – to another region of the world where the native plants have little resistance and the pathogen has eluded its natural enemies. Such events can trigger damaging disease episodes that may also have long-term negative impacts on the environment, economy and cultural heritage. Movement of plants and plant products between biogeographical zones by human activities is now generally accepted to be the primary mode of introduction of exotic pathogens and pests. There is therefore a tension, in terms of risk to the cultural and natural environment, between the conservation and environmental responsibilities of horticulturalists, foresters, garden designers and landscape architects and their desire for novel material or (these days) cheaper plants and instant trees.

Ecosystem change can occur relatively rapidly through novel pathogens. "Starting around 1910 an introduction of *Cryphonectria parasitica*, the cause of chestnut blight indigenous to China and Japan, resulted in the virtual destruction of American chestnut forests (*Castanea dentata*) through most of their natural range in the USA within thirty years" (Brasier 2008). Protections against future importations have been weakened just as the rate of global trade in potted plants and other risky materials has increased significantly. During the Clinton Administration, the federal government repealed the Plant Quarantine Act of 1912, originally passed to prevent another massive, native-tree die-off caused by an introduced pathogen. According to agricultural economist Edward A. Evans, the Plant Protection Act of 2000 superseded it to mirror more closely "the general provisions of the World Trade Organization's Sanitary and Phytosanitary Agreement" to foster international trade (Evans 2004).

Currently in North America, *P. ramorum* is only reproducing asexually, which limits the organism's capacity to adapt to changing environmental conditions. However, this could change. Two mating types and several lineages exist in North America with the NA1 (A2-mating type) predominating. The more virulent EU1 (A1-mating type), a strain from Europe, is found in a few "nurseries in California, northern Oregon, Washington, and British Columbia, Canada" (Kliejunas 2010). It has also escaped to a waterway in Humboldt Co. (Frankel 2008). The EU1 (A-1 mating type) has been found in forests in the United Kingdom and is common in European nurseries. Repeated introductions of contaminated European nursery plants have occurred despite monitoring of international trade (Goss et al. 2011). Based on efforts to mate EU1 (A-1 mating type) and NA1 (A-2 mating type) in the laboratory, it is unclear whether *P. ramorum* has a functional sexual breeding system (Brasier and Kirk 2004). If it does, the potential remains for greater disease vigor "if genetic exchange occurs between the European and American subpopulations" (Brasier and Kirk 2004). Despite the high rates of abortion, viable oospores appear to form, which means that "coexistence of both mating types on adjacent plants increases the chances for sexual recombination between these two genetically divergent lineages" (Garbelotto et al. 2006). Another indication that the impact of SOD on tanoak could worsen is that, currently, the less aggressive lineage is the more prevalent one in North America. Although rare, two other, "generally more virulent" lineages already occur in North America (Kliejunas 2010).

Based on multiple computer models, the coastal counties of Mendocino, Humboldt, and Del Norte are at high risk for widespread *P. ramorum* infection. Mild temperatures and high rainfall favor the pathogen. Also, multiple host plants grow in the region, including salal (*Gaultheria shallon* Pursh) and huckleberries (*Vaccinium* spp.). Although *P. ramorum* sporulates on a wide variety of host species, some species play more important roles in spreading the disease. California bay (*Umbellularia californica* [Hook. & Arn.] Nutt.) significantly increases disease risk, leading some researchers to advocate for its removal to reduce risk to neighboring oaks (Kliejunas 2010). Although its production of asexual spores isn't typically as prolific as California bay, tanoak too can inoculate forests with *P. ramorum*, particularly through sporangia production on leaves and twigs. Spore production begins with winter rains or shortly thereafter. Sporulation peaks with warm, spring rains and drops off to zero with hot, dry summer weather. However, in coastal areas with summer fog, inoculum persists year round (Kliejunas 2010). Wind-blown rain can assist the spread of spores. Loss of productive tanoak trees to SOD is already negatively impacting tribal communities in Sonoma Co., having spread to Kashaya Pomo Indian lands probably from neighbors who planted infected rhododendrons (D. Rizzo, University of California, personal communication). Thousands of trees have died near their 40-acre Stewarts Point Rancheria where families still harvest tanoak acorns (Ortiz 2008).

Through regulation of interstate nursery trade, the U.S. Department of Agriculture's Animal and Plant Health Inspection Service (APHIS) strives to prevent SOD spread "to noninfested areas of the United States" (Knighten and Redding 2004). In 2005, APHIS began requiring that California, Oregon, and Washington nurseries shipping "host plant nursery stock interstate, be inspected and certified free of evidence of *P. ramorum*," after four West Coast nurseries "shipped potentially infected stock to over 1200 nurseries in 39 states" (Kliejunas 2010). In regulated areas, growers must destroy infected plant material (APHIS 2010). In 2001, only one California nursery tested positive for *P. ramorum*, but by 2004 that number jumped to 176 in multiple states (Frankel and Hansen 2011). The number dropped to 34 by 2010 after APHIS began regulating the three states with known infected nurseries. But based on field investigations in 2009, *P. ramorum* spread to streams outside infested nurseries in five states (Washington, Mississippi, Alabama, Georgia, and Florida) (Frankel and Hansen 2011). A number of southeast U.S. forest species are vulnerable to *P. ramorum*, including 18 species of red oak (*Quercus* spp.), which became dominant after the demise of American elm (*Ulmus americana* L.) and American chestnut (Kluza et al. 2007). *Phytophthora* spp. that can infect forest plants are a biosecurity threat. As a result, APHIS established a protocol in 2006 for responding to *P. ramorum* outbreaks in forest and wildland environments; however, as of 2011, "no Federal response protocol for new wildland incursions" exists (Frankel and Hansen 2011). "The continued spread of this and other new *Phytophthora* spp. presents significant impetus for adjustments in the management and regulation of forest pathogens and nursery stock" (Frankel 2008).

Despite the federal quarantine administered by APHIS, various states have attempted to establish supplemental quarantines to protect their natural resources and industries. However, APHIS has yet to approve a "special need request" or SNR. A review of APHIS administration of the SOD quarantine indicates that "the SNR process has not achieved Congress' goal of allowing limited state regulation that is more restrictive than federal requirements" (Porter and Robertson 2011). Read Porter, a senior attorney with the Environmental Law Institute and Nina Robertson, a law clerk with the U.S. District

Court for the District of Columbia, defend states' rights in protecting against invasive species and call for an improved SNR process to avoid "the spread of pests into areas where they are not yet present but are likely to cause substantial harm to the economy and environment." Currently, the interests of industry prevail according to Porter and Robertson (2011). "By focusing on facilitation of trade and reduction of risks rather than prevention, Congress in effect created a preference for leaky quarantines and for trade over environmental protection." Nor have the courts upheld states' rights to reduce the risk of *P. ramorum* infection. In 2004, the California Association of Nurseries and Garden Centers sued and won to block Kentucky and nine other states from enforcing their own SOD quarantines on horticultural products shipped from California, interstate commerce valued at roughly $500 million annually (Hirsch 2004). Justice James McReynolds may prove prophetic when he warned in 1926, "[i]t is a serious thing to paralyze the efforts of a state to protect her people against impending calamity, and leave them to the slow charity of a far-off and perhaps supine federal bureau" (Oregon-Washington Railroad & Navigation Company v. Washington, 270 U.S. 87, 103 [1926], Justices McReynolds & Sutherland dissenting, as cited in Porter and Robertson 2011).

Quarantines and vigilance provide some protection for our forests from exotic disease species. But their effectiveness is limited for a number of reasons. Current methods of testing are not sensitive enough to reliably and consistently detect them (Brasier 2008). Furthermore, predicting destructive foreign organisms is not always possible because "most are unknown or innocuous in their native forests" (Schowalter et al. 1997). Confirmation of *P. ramorum* requires culturing and microscopy or molecular analysis, which can delay detection. Unfortunately, some nurseries are noncompliant with regulations and/or best practices (Brasier 2008), plus only a tiny fraction of the landscape plants produced for sale are tested. Because the detection of potential plant pathogens is difficult, Evans (2004) calls "the potential gains from [international] trade ... questionable." Susan Frankel, the SOD Research Program leader for the U.S. Forest Service, and Everett Hansen, an Oregon State University SOD researcher, note that "tools designed to protect forests and nurseries need refinement" (Frankel and Hansen 2011). Brasier (2008) more urgently calls for reform because global market influences have contributed to making "international plant biosecurity protocols ... outmoded, flawed, institutionalized, and too ineffectual." He advocates that they "be fully scientifically reviewed and appropriately overhauled, taking full account of the underlying scientific weaknesses and of the many other causes of security failure" (Brasier 2008).

Sudden Oak Death Response

Given our inability to prevent all introductions of exotic diseases, plant pathologists advocate quick response to early detections to limit their impact (Meentemeyer et al. 2004; MacLeod et al. 2010). In an effort to reduce *P. ramorum* spore production and subsequent spread, the Oregon Department of Agriculture required removal and burning of "all infected plants and all host plants growing within a 15–30 m buffer zone beyond symptomatic tanoak trees" near the town of Brookings (Curry Co.). The treatment typically includes herbicides to limit tanoak resprouting (Hansen et al. 2008). Oregon's infestation, as well as disjunct outbreaks in Mendocino and Humboldt counties in northern California, concern scientists given their potential to catalyze landscape-scale infection in a high-risk area. An infection near the town of Redway (Humboldt Co.) is worrisome to plant pathologists since it is a significant distance from other infestations and provides a northern foothold for the pathogen in California (Fig. 10) (Meentemeyer et al. 2011). Of even greater concern is an infection found farther north outside of Redwood National Park (NPS 2013). "In the absence of extensive control," Meentemeyer et al. (2011) "predict a ten-fold increase in disease spread between 2010 and 2030 with most infection concentrated along the north coast between San Francisco and Oregon". As a result, "substantial tree mortality, particularly of tanoak, is likely to follow." Based on their computer model, they predict "explosive growth in infection and disease ... to occur around 2016." Although it is unlikely that *P. ramorum* will cause tanoak extinction, it will likely cause "the rapid and extensive loss of overstorey trees ... within 30 years of pathogen establishment in many forests" (Cobb et al. 2012).

Pesticides cannot feasibly be used to control SOD on a landscape scale. Many pesticides used on other species in the genus *Phytophthora* test as effective against *P. ramorum* under experimental conditions (Kliejunas 2010). Currently Agri-Fos® is recommended as a prophylactic if applied twice in the first year and then annually after that (Kliejunas 2010). In rugged areas with limited access, intensive pesticide treatments are prohibitively expensive if commercial applicators are used or if the work is logistically difficult. Plus, pesticide use is widely unpopular in northern California and poses a significant political liability for those proposing synthetic chemical intervention (Van Strum 1983; Bowcutt 1999). Future use of pesticides in forest settings requires public support (Whitfield 1992).

Fire and Forest Pathogens

The health status of a particular tree may not be a significant factor in the SOD epidemic

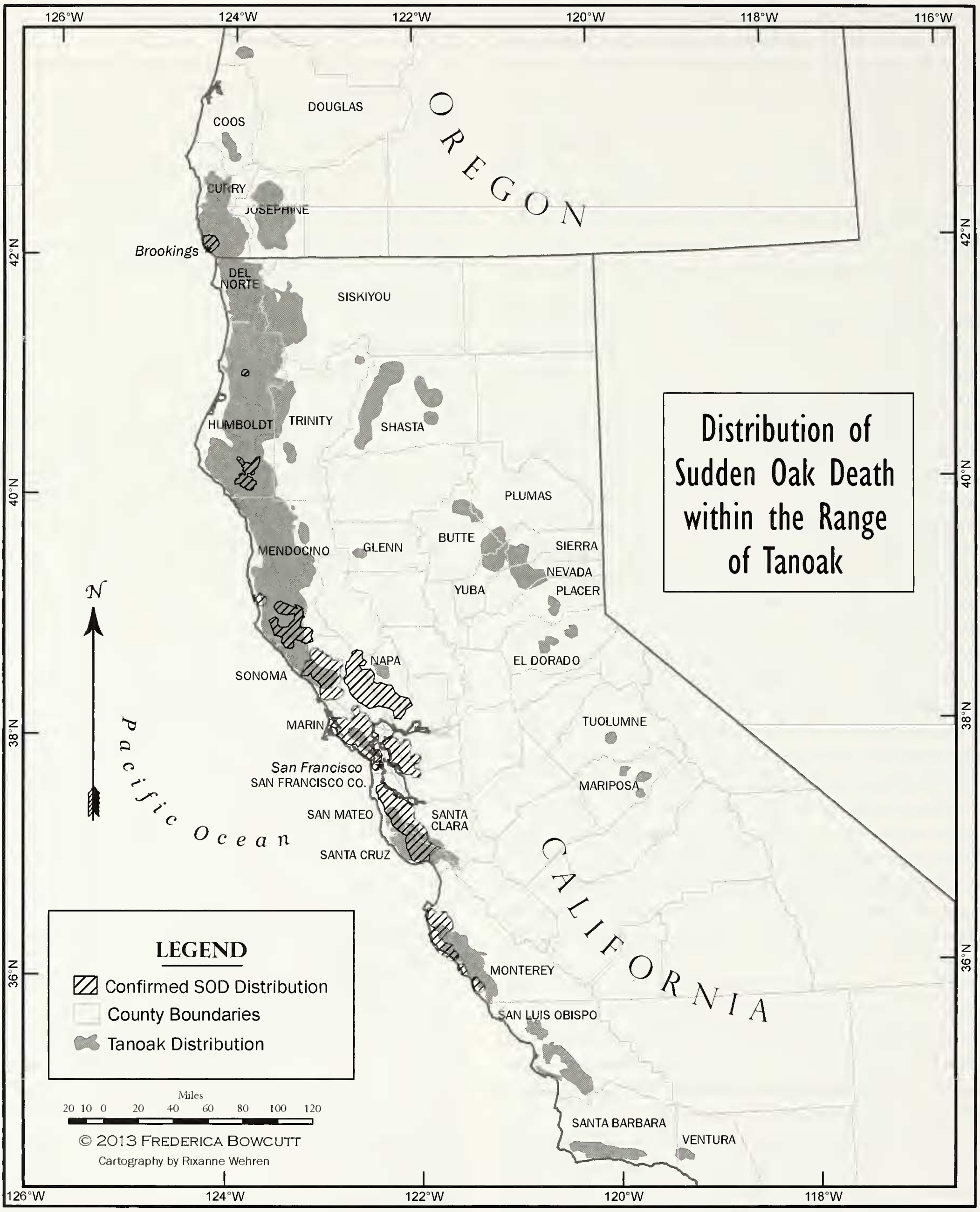

FIG. 10. Sudden oak death distribution in relationship with tanoak distribution. Data sources: data on California and Oregon distribution as of February 20, 2012 came from Geospatial Innovation Facility (2012). A few additional sites were added from U.C. Berkeley Forest Pathology and Mycology Laboratory (2012). Oregon sudden oak death distribution as of March 14, 2012 came from the Oregon Department of Agriculture (2012). The tanoak distribution data for California came from Griffin and Critchfield 1976. Tanoak distribution data for Oregon came from the Oregon Flora Project (2012).

because *P. ramorum* is a novel pathogen in North America, and tanoak currently exhibits little resistance. However, other forest insect and disease epidemics often link to "environmental stresses that predispose trees to being attacked and killed by secondary agents" (California Oak Mortality Task Force 2011). In Yosemite National Park, termination of natural and Native American fire regimes caused colonization of oak woodlands by conifers, resulting in increased competition for light, water, and nutrients. "As oaks have become stressed due to suppression by encroaching conifers, they have succumbed to several canker rots" (Rizzo and Slaughter 2001).

Prior to Euro-American settlement, Native peoples burned Yosemite Valley to control for black oak diseases and to release oaks from conifer competition. A 2005 study suggested tanoak vulnerability to SOD increased with fire exclusion (Moritz and Odion 2005). However, these results have been challenged given the limitations of SOD distribution and fire-history maps, which make studying the relationship between "pathogen invasion and persistence" and burning difficult (Lee 2009).

Fires don't appear to immunize forests. Nor do prescribed burning or catastrophic wildfires eliminate *P. ramorum* from a site, though they can reduce its spread (Lee 2009). Preliminary results from experimental treatments in southwestern Oregon and northern California forests suggest "that burning can be a valuable tool in cleaning up small infectious material in infested sites," even when it doesn't eliminate the pest (Lee 2009). Thus far, frequent, low-intensity fires that mimic traditional ecological practices of indigenous peoples experienced with managing tanoak have not yet been tested as a prophylactic measure or to treat an infected site. Many California Indians are deeply committed to continued use of tanoak acorns and seek partnerships to address the *P. ramorum* threat (Ortiz 2008). An increasing number of commentators question exclusively relying on scientific expertise at the expense of other forms of knowledge when making decisions about environmental issues that impact stakeholders. They advocate for "partnerships between experts, policy advisers and stakeholders" that embrace "participatory approaches" (MacLeod et al. 2010).

Tanoak Cultural Landscapes

Existing public lands provide opportunities for safeguarding tanoak. However, many are already infested with the SOD pathogen (Appendix 1). Park visitors and neighboring gardeners unwittingly have become disease vectors. Establishing management practices designed to reduce infection risk in uninfected parks on the north coast of California makes sense given that scientists predict explosive disease expansion in this region. Redwood National and State Parks (RNSP) are at high infection risk due to multiple vehicular entry points and high visitation combined with a favorable climate and an abundance of suitable hosts. Redwood Creek has tested positive for *P. ramorum* in the park. Although no plants appear diseased, the "infection source is approximately 5 mi (8 km) southeast of the Park boundary and could eventually move into RNSP forests" (NPS 2013). RNSP natural-resource managers are preparing for "the inevitable arrival of *P. ramorum* to the parks" by adopting preventive measures to slow its spread once it arrives. Park managers recognize tanoak as a valuable ecological component of the coast redwood forest in the park. "RNSP also has an important cultural legacy of large stands of old tanoak trees that have been managed by Native American families for many generations" (Bueno et al. 2010). Park managers are considering "creating tanoak refuges (defined as tanoak groves that are least likely to become infected due to spatial or temporal factors)" (Bueno et al. 2010). Based on epidemiological modeling, widely spaced tanoaks associated with plants that are immune to *P. ramorum* infection "resulted in slow-enough transmission to retain overstorey tanoak" (Cobb et al. 2012). Manipulating vegetation to create conditions unfavorable to the pathogen prior to disease arrival could radically reduce risk.

Sinkyone Wilderness State Park could serve as another tanoak refuge in this North Coast zone of high risk. It occurs on the longest stretch of undeveloped coastline in the 48 contiguous states with a large buffer of undeveloped land. Limited road access makes temporary park closures feasible during the period the disease is most active (March–May) to reduce the risk of humans accidentally spreading the disease. The watersheds in the park are minimally developed further reducing the risk of infected waterways spreading the pathogen. Introduction of infected nursery plants in the area is less likely due to the low number of neighboring ranchettes. Although the park appears to be uninfected, new outbreaks are increasingly encroaching (Peterson 2012), so reducing infection risks now may safeguard tanoaks. A risk-reduction plan could be developed based on current best practices, including prohibiting potentially contaminated material in tanoak cultural landscapes. Given that the ethnographic record indicates annual, low-intensity ground fires can be effective against other kinds of tanoak diseases, it is worth investigating if this traditional ecological knowledge could help address the current SOD crisis.

Case studies from western North America offer us models of how partnerships involving tribal groups can help to repair environmental and social damage. For example, the Nisqually Tribe, the U.S. Fish and Wildlife Service, and several nonprofit organizations restored the Nisqually River Delta to an estuary 100 years after it was diked for agriculture (Middleton 2011). Within the Six Rivers National Forest, Yurok, Karok, and Hoopa elders advised on "a series of experimental burns to enhance the quality and quantity of … beargrass," which is used by tribal members for basket making (Anderson 1993). These partnerships didn't restore what's been lost, but they did begin to heal the damage. Given significant changes to forest systems, reintroducing fire alone won't address the challenges facing tanoak. Any potential benefits will need to be weighed against the risks, but that analysis needs to occur in a way that involves Native people with a stake in tanoak wellness.

Conclusions

Concerted action is needed due to the threat posed by *P. ramorum*. Tanoak plays key roles in coast redwood forests and other ecosystems. It is the most abundant hardwood in California, the only species in its genus, and its acorns still serve Native peoples as a beloved, indigenous food. Fortunately, the heartland of tanoak's distribution is mostly uninfected. Timely intervention is important because of tanoak's ecological and cultural significance. To be fully successful, actions to protect tanoak should:

- involve tribal leadership in each step of its development and implementation,
- make recommendations on infection risk reduction strategies for tanoak cultural landscapes,
- address widespread concerns about pesticide use,
- suggest policy changes to address the continued spread of *P. ramorum*, such as greater restrictions on the movement of susceptible garden plants, and
- develop plans for testing traditional ecological knowledge—namely frequent, low-intensity fires—for treating infested sites and reducing infection risk.

We need to proactively safeguard and cultivate local food sovereignty, including the use of perennial native plants. Used in this way, tanoak might more accurately be called by its other common name: sovereign oak.

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Literature Cited

American Philosophical Society. 2012. Native American audio collections. American Philosophical Society, Philadelphia, PA.Website: www.amphilsoc.org/exhibit/natamaudio/yuki [accessed 30 October 2012].

Anderson, K. 1993. Native Californians as ancient and contemporary cultivators. Pp. 151–174 *in* T. C. Blackburn and K. Anderson, (eds.), Before the wilderness environmental management by Native Californians. Ballena Press, Menlo Park, CA.

Anderson, M. K. 2005. Tending the wild: Native American knowledge and the management of California's natural resources. University of California Press, Berkeley, CA.

Anderson, R. S. and S. L. Carpenter. 1991. Vegetation change in Yosemite Valley, Yosemite National Park, California during the protohistoric period. Madroño 38:1–13.

Animal and Plant Health Inspection Service (APHIS). 2010. United States Department of Agriculture. Confirmed Nursery Protocol. Website: http://www.aphis.usda.gov/plant_health/plant_pest_info/pram/protocols.shtml#response [accessed 12 February 2013].

Baker, M. A. 1981. The ethnobotany of the Yurok, Tolowa, and Karok Indians of northwest California. M.S. thesis. Humboldt State University, Arcata, CA.

Barrett, S. A. 1964. The beautiful tree–Chishkale. The American Indian Series 16 mm motion picture. University of California Extension Media Center, Berkeley, CA.

Basgall, M. E. 1987. Resource intensification among hunter-gatherers: acorn economies in prehistoric California. Pp. 21–52 *in* B. L. Isaac (ed.), Research in economic anthropology, Vol. 9. JAI Press, Greenwich, CT.

Baumhoff, M. A. 1963. Ecological determinants of aboriginal California populations. University of California Publications in American Archaeology and Ethnology 49:155–236.

———. 1978. Environmental background. Pp. 16–24 *in* R. F. Heizer (ed.), Handbook of North American Indians, Vol. 8, California. Smithsonian Institution, Washington D.C.

Beard, Y. S. 1979. The Wappo: a report. Malki Museum Press, Morongo Indian Reservation, Banning, CA.

Berkes, F. 1999. Sacred ecology: traditional ecological knowledge and resource management. Taylor & Francis, Philadelphia, PA.

Bledsoe, A. J. 1885. Indian wars of the Northwest: a California sketch. Bacon & Company, Book and Job Printers, San Francisco, CA.

Bocek, B. R. 1984. Ethnobotany of Costanoan Indians, California, based on collections by John P. Harrington. Economic Botany 38:240–255.

Bowcutt, F. 1994–1996. A floristic study of Sinkyone Wilderness State Park, Mendocino County, California. Wasmann Journal of Biology 51:64–143.

———. 1996. Wild restoration: building multicultural partnership in the Sinkyone Wilderness. Ph.D. dissertation. University of California, Davis, CA.

———. 1999. Ecological restoration and local communities: a case study from Sinkyone Wilderness State Park, Mendocino County, California. Human Ecology 27:359–368.

———. 2011. Tanoak target: the rise and fall of herbicide use on a common native tree. Environmental History 16:197–225.

Brasier, C. M. 2008. The biosecurity threat to the U.K. and global environment from international trade in plants. Plant Pathology 57:792–808.

——— and S. A. Kirk. 2004. Production of gametangia by *Phytophthora ramorum* in vitro. Mycological Research 108:823–827.

Briles, C. E., C. Whitlock, and P. J. Bartlein. 2005. Postglacial vegetation, fire, and climate history of the Siskiyou Mountains, Oregon, USA. Quaternary Research 64:44–56.

Bueno, M., J. Deshais, L. Arguello. 2010. Waiting for SOD: sudden oak death and Redwood National and State Parks. Pp. 297–301 *in* , S. J. Frankel, J. T. Kliejunas, and K. M. Palmieri (tech. coords.), Proceedings of the Sudden Oak Death Fourth Science Symposium. General Technical Report PSW-GTR-229. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, CA.

California Oak Mortality Task Force. 2011. Ecology of Tree Diseases. Website: http://www.suddenoakdeath.org/about-sudden-oak-death/ecology-of-tree-diseases/ [accessed 29 May 2011].

California Oak Mortality Task Force. 2012. California Oak Mortality Task Force Report- June 2012. Website: http://www.suddenoakdeath.org/wp-content/uploads/2012/06/COMTF-Report-June-2012.pdf [accessed 11 July, 2012].

Centers for Disease Control and Prevention (CDC). 2011. Trends in diabetes prevalence among American Indian and Alaska Native children, adolescents, and young adults—1990–1998. Website: http://www.cdc.gov/diabetes/pubs/factsheets/aian.htm [accessed 27 August 2011].

Chartkoff, J. L. and K. K. Chartkoff. 1984. The archaeology of California, Stanford University Press, Stanford, CA.

Chestnut, V. K. 1974. Plants used by the Indians of Mendocino County, California. Contributions from the U.S. National Herbarium, Vol. 7. Reprinted by the Mendocino County Historical Society, Ukiah, CA.

Cobb, R. C., J. A. N. Filipe, R. K. Meentemeyer, C. A. Gilligan, and D. M. Rizzo. 2012. Ecosystem transformation by emerging infectious disease: loss of large tanoak from California forests. Journal of Ecology 100:712–722.

Curtin, L. S. M. 1957. Some plants used by the Yuki Indians of Round Valley, northern California (with historical review and photos by M. C. Irwin). Southwest Museum Leaflets, no. 27. Southwest Museum, Los Angeles, CA.

Davis, B. J. 1991. Plants and the people: the ethnobotany of the Karuk Tribe. Siskiyou County Museum, Yreka, CA.

Driver, H. 1952. The acorn in North American Indian diet. Proceedings of the Indiana Academy of Science 62:56–62.

Essene, F. 1942. Cultural element distributions: XXI Round Valley. University of California Anthropological Records 8:1–97.

Evans, E. A. 2004. Potential problems facing the U.S. nursery industry. Department of Food and Resource Economics, University of Florida IFAS Extension, EDIS document FE491. Website: http://edis.ifas.ufl.edu/pdffiles/FE/FE49100.pdf [accessed 20 August 2012].

Frankel, S. J. 2008. Sudden oak death and *Phytophthora ramorum* in the USA: a management challenge. Australasian Plant Pathology 37:19–25.

——— and E. M. Hansen. 2011. Forest *Phytophthora* diseases in the Americas: 2007–2010. New Zealand Journal of Forestry Science 41S:S159–164.

Freinkel, S. 2007. American chestnut: the life, death, and rebirth of a perfect tree. University of California Press, Berkeley, CA.

Fryer, J. L. 2008. *Lithocarpus densiflorus. In* Fire Effects Information System [Online]. U.S. Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. Website: http://www.fs.fed.us/database/feis/plants/tree/litden/all.html [accessed 21 August 2012].

Garbelotto, M., K. Ivors, D. Huberli, P. Bonants, and A. Wagner. 2006. Potential for sexual reproduction of *Phytophthora ramorum* in Washington State nurseries. P. 129 *in* S. J. Frankel, P. J. Shea, and M. I. Haverty, (eds.), Proceedings of the Sudden Oak Death Second Science Symposium: the state of our knowledge, January 18–21, 2005, Monterey, California, General Technical Report PSW-GTR-196. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, CA.

Geospatial Innovation Facility. 2012. Distribution of sudden oak death as of February 20, 2012. OakMapper: monitoring sudden oak death. Geospatial Innovation Facility and Kelly Research & Outreach Lab. University of California, Berkeley, CA. Website: www.oakmapper.org/pdf/California.pdf [accessed 30 October 2012].

Gifford, E. W. 1967. Ethnographic notes on the southwestern Pomo. University of California Anthropological Records 25:1–48.

———. 1968. California balanophagy. Pp. 87–98 *in* Essays in Anthropology, presented to A. L. Kroeber in celebration of his sixtieth birthday, June 11, 1936. Books for Libraries Press, Inc., Freeport, N.Y. reprinted in 1968 by arrangement with the University of California Press, Berkeley, CA.

———. 1971. Californian balanophagy. Pp. 301–305 *in* R. F. Heizer and M. A. Whipple, (eds.), The California Indians: a source book, second edition revised and enlarged. University of California Press, Berkeley, CA.

Gilliland, L. E. 1985. Proximate analysis and mineral composition of traditional California Native American foods. M.S. thesis. University of California, Davis, CA.

Goodrich, J., C. Lawson, and V. P. Lawson. 1980. Kashaya Pomo plants, American Indian Monograph Series No. 2. American Indian Studies Center, University of California, Los Angeles, CA.

Gould, R. A. 1976. Ecology and adaptive response among the Tolowa Indians of northwestern California. Pp. 49–78 *in* L. J. Bean and T. C. Blackburn, (eds.), Native Californians: a theoretical retrospective. Ballena Press, Socorro, N.M.

Goss, E. M., M. Larsen, A. Vercauteren, S. Werres, K. Heungens, and N. J. Grünwald. 2011. *Phytophthora ramorum* in Canada: evidence for migration within North America and from Europe. Phytopathology 101:166–171.

Greene, E. L. 1889. Illustrations of West American oaks: from drawings of the late Albert Kellogg, M.D. Published with funds from James M. McDonald, Esq., San Francisco, CA.

GRIFFIN, J. R. AND W. B. CRITCHFIELD. 1976. The distribution of forest trees in California. Research Paper PSW-82. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Berkeley, CA.

GRÜNWALD, N. J., M. GARBELOTTO, E. M. GOSS, K. HEUNGENS, AND S. PROSPERO. 2012. Emergence of the sudden oak death pathogen *Phytophthora ramorum*. Trends in Microbiology 20:131–138.

HANSEN, E. M., A. KANASKIE, S. PROSPERO, M. MCWILLIAMS, E. M. GOHEEN, N. OSTERBAUER, P. REESER, AND W. SUTTON. 2008. Epidemiology of *Phytophthora ramorum* in Oregon tanoak forests. Canadian Journal of Forest Research 38:1133–1143.

HAYDEN, K. J., A. NETTEL, R. S. DODD, AND M. GARBELOTTO. 2011. Will all the trees fall? Variable resistance to an introduced forest disease in a highly susceptible host. Forest Ecology and Management 261:1781–1791.

HEIZER, R. F. AND A. B. ELSASSER. 1980. The natural world of the California Indians. University of California Press, Berkeley, CA.

HIRSCH, J. 2004. Nursery group wins dispute. Los Angeles Times, August 3, 2004.

HOSTEN, P. E., O. E. HICKMAN, F. K. LAKE, F. A. LANG, AND D. VESELY. 2006. Oak woodlands and savannas. Pp. 63–96 *in* D. Apostol and M. Sinclair, (eds.), Restoring the Pacific Northwest: the art and science of ecological restoration in Cascadia. Island Press, Washington, D.C.

INTEGRATED TAXONOMIC INFORMATION SYSTEM (ITIS). 2011, Website: http://www.itis.gov [accessed 18 September 2011].

IVORS, K., M. GARBELOTTO, I. D. E. VRIES, C. RUYTER-SPIRA, B. T. E. HEKKERT, N. ROSENZWEIG, AND P. BONANTS. 2006. Microsatellite markers identify three lineages of *Phytophthora ramorum* in US nurseries, yet single lineages in US forest and European nursery populations. Molecular Ecology 15:1493–1505.

JEPSON, W. L. 1909. The trees of California. Cunningham, Curtis & Welch, San Francisco, CA.

———. 1910. The silva of California. Memoirs of the University of California Vol. 2. The University Press, Berkeley, CA.

———. 1911. Tanbark oak and the tanning industry. California tanbark oak – Part II, U.S. Forest Service Bulletin 75. Government Printing Office, Washington, D.C.

KELLY, M. 2011. Erratic, extreme day-to-day weather puts climate change in new light. News at Princeton, Princeton University. Website: http://www.princeton.edu/main/news/archive/S32/13/25I02/index.xml?section=topstories [accessed 10 February 2013].

KLIEJUNAS, J. 2010. Sudden oak death and *Phytophthora ramorum*: a summary of the literature. General Technical Report PSW-GTR-234. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, CA.

KLUZA, D. A., D. A. VIEGLAIS, J. K. ANDREASEN, AND A. T. PETERSON. 2007. Sudden oak death: geographic risk estimates and predictions of origins. Plant Pathology 56:580–587.

KNIFFEN, F. B. 1939. Pomo geography. University of California Publications in American Archaeology and Ethnology 36:353–400.

KNIGHTEN, C. AND J. REDDING. 2004. USDA takes action in three states to halt spread of plant fungus. News release of the United States Department of Agriculture Animal and Plant Health Inspection Service. Website: http://www.aphis.usda.gov/newsroom/hot_issues/sod/sod_12_2004.shtml [accessed 11 February 2013].

KROEBER, A. L. 1919. Sinkyone tales. Journal of American Folklore 32:346–351.

——— AND E. W. GIFFORD. 1949. World renewal, a cult system of native northwest California. University of California Anthropological Records 13:1–156.

LEE, C. 2009. Sudden oak death and fire - 2009 update. California Oak Mortality Task Force. Website: http://www.suddenoakdeath.org/pdf/summary%20of%20fire%20and%20p%20ramorum%20issues%20v5.3.pdf [accessed 15 January 2012].

LEWIS, H. T. 1993. Patterns of Indian burning in California: ecology and ethnohistory. Pp. 55–116 *in* T. C. Blackburn and K. Anderson, (eds.), Before the wilderness environmental management by Native Californians. Ballena Press, Menlo Park, CA.

LIGHTFOOT, K. G. 2005. Indians, missionaries, and merchants: the legacy of colonial encounters on the California frontiers. University of California Press, Berkeley, CA.

LOUD, L. L. 1918. Ethnography and archaeology of the Wiyot Territory. University of California Publications in American Archaeology and Ethnology 14:221–436.

MACLEOD, A., M. PAUTASSO, M. J. JEGER, AND R. HAINES-YOUNG. 2010. Evolution of the international regulation of plant pests and challenges for future plant health. Food Security 2:49–70.

MARSHALL, W. 1984. The art of making acorn soup. *In* Fall 2008 Newsletter. Phoebe A. Hearst Museum of Anthropology, University of California Berkeley, CA.Website: http://hearstmuseum.berkeley.edu/about/newsletter/2008-fall [accessed 10 February 2013].

MASCHERETTI, S., P. J. P. CROUCHER, A. VETTRAINO, S. PROSPERO, AND M. GARBELOTTO. 2008. Reconstruction of the sudden oak death epidemic in California through microsatellite analysis of the pathogen *Phytophthora ramorum*. Molecular Ecology 17:2755–2768.

MCCARTHY, H. 1993. Managing oaks and the acorn crop. Pp. 213–228 *in* T. C. Blackburn and K. Anderson, (eds.), Before the wilderness: environmental management by Native Californians. Ballena Press, Menlo Park, CA.

MCDONALD, P. M. AND D. W. HUBER. 1995. California's hardwood resource: managing for wildlife, water, pleasing scenery, and wood products. General Technical Report PSW-GTR-154. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, CA.

———, J. C. TAPPEINERII. 1987. Silviculture, ecology, and management of tanoak in northern California. Pp. 64–70 *in* T. R. Plumb, AND N. H. Pillsbury (tech. coords.), Proceedings of the Symposium on Multiple-use Management of California's Hardwood Resources, November 12-14, 1986, San Luis Obispo, California. General Technical Report PSW-100. Pacific Southwest Forest and Range

Experiment Station, Forest Service, U.S. Department of Agriculture, Berkeley, CA.

McPherson, B. A., S. R. Mori, D. L. Wood, A. J. Storer, P. Svihra, N. M. Kelly, and R. B. Standiford. 2005. Sudden oak death in California: disease progression in oaks and tanoaks. Forest Ecology and Management 213:71–89.

Medvigy, D. and C. Beaulieu. 2012. Trends in daily solar radiation and precipitation coefficients of variation since 1984. Journal of Climate 25:1330–1339.

Meentemeyer, R. K., N. J. Cunniffe, A. R. Cook, J. A. N. Filipe, R. D. Hunter, D. M. Rizzo, and C. A. Gilligan. 2011. Epidemiological modeling of invasion in heterogeneous landscapes: spread of sudden oak death in California (1990–2030). Ecosphere 2:art 17, doi:10.1890/ES10-00192.1.

———, D. Rizzo, W. Mark, and E. Lotz. 2004. Mapping the risk of establishment and spread of sudden oak death in California. Forest Ecology and Management 200:195–214.

Middleton, B. R. 2011. Trust in the land: new directions in tribal conservation. The University of Arizona Press, Tucson, AZ.

Moritz, M. and D. C. Odion. 2005. Examining the strength and possible causes of the relationship between fire history and sudden oak death. Oecologia 144:106–114.

National Park Service (NPS). 2013. Sudden oak death. Redwood National and State Parks. Website: http://www.nps.gov/redw/naturescience/sod.htm [accessed 10 February 2013].

Nixon, K. C. 1997. Fagaceae. Pp. 436–506 *in* Flora of North America Editorial Committee (eds.). 1997, Flora of North America: North of Mexico, Vol. 3 Magnoliophyta: Magnoliidae and Hamamelidae. Oxford University Press, Oxford, U.K.

Nomland, G. A. 1935. Sinkyone notes. University of California Publications in American Archaeology and Ethnology 36:149–178.

Oregon Department of Agriculture. 2012. Sudden oak death, Curry County, OR, 14 March 2012. ODA, Commodity Inspection, Plant Health. Oregon Department of Agriculture, Salem, OR. Website: www.oregon.gov/ODA/CID/PLANT_HEALTH/PublishingImages/lg/sodquar2012.jpg [accessed 29 November 2012].

Oregon Flora Project. 2012. Oregon plant atlas. Oregon Flora Project. Oregon State University, Corvallis, OR. Website: www.oregonflora.org/atlas.php [accessed 26 November 2012].

Ortiz, B. R. 2008. Contemporary California Indian uses for food of species affected by *Phytophthora ramorum*. Pp. 419–425 *in* S. J. Frankel, J. T. Kliejunas, and K. M. Palmieri (tech. coords.), Proceedings of the Sudden Oak Death Third Science Symposium. General Technical Report PSW-GTR-214. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, CA.

Peattie, D. C. 1991. A natural history of western trees. Houghton Mifflin Company, Boston, MA.

Peterson, U. 2012. Sudden oak death continues to spread in the Mattole Watershed. Mattole Restoration News #37 Winter/Spring issue, 15–16.

Porter, R. D. and N. C. Robertson. 2011. Tracking implementation of the special need request process under the Plant Protection Act. Environmental Law Reporter 41:11000–11019.

Prain, D. (ed.) 1917, Curtis's botanical magazine, illustrating and describing plants of the Royal Botanic Gardens of Kew and of other botanical establishments, Vol. 13 of the fourth series. L. Reeve & Co., Ltd., London, U.K.

Radtke, L. B. 1937. The tan oak, friend of the Hoopa Valley Indians: shall we destroy it? Indians at Work. Office of Indian Affairs, Washington, D.C.

Raphael, M. G. 1987. Wildlife-tanoak associations in Douglas-fir forests of northwestern California. Pp. 183–189 *in* T. R. Plumb and N. H. Pillsbury (tech. coords.), Proceedings of the Symposium on Multiple-use Management of California's Hardwood Resources, November 12–14, 1986, San Luis Obispo, California, General Technical Report PSW-100. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Berkeley, CA.

Reid, L. J., N. G. Sugihara. 1987. Northern oak woodlands—ecosystems in jeopardy or is it already too late? Pp. 59–63 *in* T. R. Plumb and N. H. Pillsbury (tech. coords.), Proceedings of the Symposium on Multiple-use Management of California's Hardwood Resources, November 12-14, 1986, San Luis Obispo, California, General Technical Report PSW-100. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Berkeley, CA.

Rizzo, D. M. and G. W. Slaughter. 2001. Root disease and canopy gaps in developed areas of Yosemite Valley, California. Forest Ecology and Management 146:159–167.

———, M. Garbelotto, and E. M. Hansen. 2005. *Phytophthora ramorum*: integrative research and management of an emerging pathogen in California and Oregon forests. Annual Review of Phytopathology 43:309–335.

———, ———, J. M. Davidson, G. W. Slaughter, S. T. Koike. 2002a. *Phytophthora ramorum* and sudden oak death in California: I. Host relationships. Pp. 733–740 *in* R. B. Standiford, D. McCreary, and K. L. Purcell (tech. coords.), Proceedings of the Fifth Symposium on Oak Woodlands: oaks in California's changing landscape, October 22–25, 2001, San Diego, CA PSW-GTR-184. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, CA.

———, ———, ———, ———, and ———. 2002b. *Phytophthora ramorum* as the cause of extensive mortality of *Quercus* spp. and *Lithocarpus densiflorus* in California. Plant Disease 86:205–214.

Roy, D. F. 1957a. A record of tanoak acorn and seedling production in northwestern California. Forest Research Notes no. 124:1–6. California Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Berkeley, CA.

———. 1957b. Silvical characteristics of tanoak. Technical Paper No. 22. California Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Berkeley, CA.

———. 1962. California hardwoods: management practices and problems. Journal of Forestry 60:184–186.

Sargent, C. S. 1859. The silva of North America: a description of the trees which grow naturally in North America exclusive of Mexico, Vol. 8. Houghton, Mifflin and Company, New York, NY.

Schaeffer, C. E. 1959. Indian tribes and languages of the old Oregon country: a new map. Oregon Historical Quarterly 60:129–133.

Schenck, S. M. and E. W. Gifford. 1952. Karok Ethnobotany. University of California Anthropological Records 13:377–392.

Schniewind, A. P. 1958. The strength and related properties of tanoak. California Forestry and Forest Products, No. 7. Forest Products Laboratory, California Agricultural Experiment Station, University of California, Berkeley, CA.

Schowalter, T., E. Hansen, R. Molina, and Y. Zhang. 1997. Integrating the ecological roles of phytophagous insects, plant pathogens, and mycorrhizae in managed forests. Pp. 171–189 *in* K. A. Kohm and J. F. Franklin (eds.), Creating a forestry for the 21st century: the science of ecosystem management. Island Press, Washington, D.C.

Shanks, R. and L. W. Shanks. 2006. Indian baskets of central California. Costaño Books, Novato, CA distributed by University of Washington Press.

Tappeiner, II, J. C., P. M. McDonald, and D. F. Roy. 1990. *Lithocarpus densiflorus* (Hook. & Arn.) Rehd. Tanoak. Pp. 417–425 *in* R. M. Burns and B. H. Honkala (tech. coords.), Silvics of North America, Vol. 2, hardwoods. Agriculture Handbook 654, U.S. Forest Service, Washington, D.C.

Tucker, J. M. 2012. Fagaceae. Pp. 802–808 *in* B. G. Baldwin, D. H. Goldman, D. J. Keil, R. Patterson, T. J. Rosatti, and D. H. Wilken, (eds.), The Jepson manual: vascular plants of California, second edition. University of California Press, Berkeley, CA.

———, W. E. Sundahl, and D. O. Hall. 1969. A mutant of *Lithocarpus densiflorus*. Madroño 20:221–225.

U. C. Berkeley Forest Pathology and Mycology Laboratory. 2012. SODMAP project. University of California, Berkeley, CA. Website: www.sodmap.org [accessed 6 December 2012].

Vander Wall, S. B. 2001. The evolutionary ecology of nut dispersal. Botanical Review 67:74–117.

Van Strum, C. 1983. A bitter fog: herbicides and human rights. Sierra Club Books, San Francisco, CA.

Vitousek, P. M., C. M. D'Antonio, L. L. Loope, and R. Westbrooks. 1996. Biological invasions as global environmental change. American Scientist 84:468–478.

Wallace, W. 1978. Hupa, Chilula, and Whilkut. Pp. 164–179 *in* R. F. Heizer (ed.), Handbook of North American Indians, Vol. 8, California. Smithsonian Institution, Washington, D.C.

Warburton, A. D. and J. F. Endert. 1966. Indian lore of the north California coast. Pacific Pueblo Press, Santa Clara, CA.

Whitfield, L. 1992. Summary - the status and future of pesticide use in California. P. 32 *in* D. Adams and J. Rios (tech. coords.), California Forest Pest Council Proceedings of the 41st Annual Meeting, Redding, California, November 18-19, 1992. California Pest Council, Sacramento, CA.

Wilkinson, W. H., P. M. McDonald, and P. Morgan. 1997. Tanoak sprout development after cutting and burning in a shade environment. Western Journal of Applied Forestry 12:21–26.

Wolf, C. B. 1945. California wild tree crops: their crop production and possible utilization. Rancho Santa Ana Botanic Garden, Santa Ana Cañon, CA.

Appendix 1

Partial List of Sudden Oak Death Infected Public Lands in the Range of Tanoak

Based primarily on data from Dr. Maggi Kelly and Sam Blanchard, University of California, Berkeley, Department of Environmental Science, Policy, and Management. The Siskiyou National Forest, Oregon, infestation is according to the California Oak Mortality Task Force (2012). Abbreviations: BLM = Bureau of Land Management, MA = Management Area, NF = National Forest, NM = National Monument, NP = National Park, NRA = National Recreation Area, NS = National Seashore, OSD = Open Space District, OSP = Open Space Preserve, RA = Resource Area, RP = Regional Preserve, SF = State Forest, SHP = State Historic Park, SP = State Park, SNR = State Natural Reserve, SR = State Recreation Area, W = Wilderness. *The list of county and regional public lands is significantly abbreviated. Infected city lands are not listed.

Federal Lands: Coos Bay District, Myrtlewood RA (Oregon BLM), Golden Gate NRA, Lacks Creek MA (California BLM), Los Padres NF, Ventana W, Muir Woods NM, Presidio of San Francisco NP, Point Reyes NS, Rogue River-Siskiyou NF.

State Lands: Andrew Molera SP, Angel Island SP, Annadel SP, Armstrong Redwoods SNR, Austin Creek SRA, Big Basin Redwoods SP, Bothe-Napa Valley SP, Cape Sebastian SP, Castle Rock SP, China Camp SP, Fort Ross SHP, Hendy Woods SP, Henry Cowell Redwoods SP, Humboldt Redwoods SP, Jack London SHP, John B. Dewitt Redwoods SR, Julia Pfeiffer Burns SP, MacKerricher SP, Mailliard Redwoods SR, Mount Tamalpais SP, Navarro River Redwoods SP, Olompali SHP, Pfeiffer-Big Sur SP, Salt Point SP, Samuel P. Taylor SP, Soquel Demonstration SF, Sugarloaf Ridge SP, The Forest of Nisene Marks SP, Tomales Bay SP.

County and Regional Lands*: Anthony Chabot Regional Park, Bear Creek Redwoods OSP, Briones Regional Park, Coal Creek OSP, Crystal Springs Watershed, El Sereno OSP, Huckleberry Botanic RP, Ignatio Valley OSP, Jacobs Ranch OSP, Jasper Ridge Biological Preserve, Las Trampas Regional W, Long Ridge OSP, Los Trancos OSP, Manzanita Regional Park, Marin Municipal Water District lands, Midpeninsula Regional OSD, Mill Creek Redwood Preserve, Monte Bello OSP, Mount Burdell OSP, Palo Corona Ranch Regional Park, Rancho San Antonio OSP, Redwood Regional Park, Roys Redwoods OSP, Russian Ridge OSP, Sierra Azul OSP, Sobrante Ridge RP, Tilden Regional Park, White Hill OSP, Wildcat Canyon Regional Park.